I hereby certify that this correspondence is, on the date shown below, being filed with the U.S. Patent and Trademark Office via EFS.

/Lisa L Pringle/
Signature
Date: 1 July 2008 Lisa L. Pringle
(type or print name of person certifying)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)	
	)	
Ian Robinson, et al.	)	Group Art Unit: 2611
	)	
Serial No.: 10/606,721	)	
	)	
Filed: June 26, 2003	)	Examiner: Kevin Michael Burd
	)	

For: *Communication System and Method for Improving Efficiency*

DECLARATION UNDER 37 C.F.R. §1.131

Sir:

I, the undersigned, declare as follows:

1. I, Ian Robinson, am an inventor of the invention entitled Communication System and Method for Improving Efficiency, disclosed and claimed in U.S. Patent Application Serial No. 10/606,721 (hereinafter to as "the Application"), which was filed on June 26, 2003.

2. I along with my co-inventor, Frank Winter, conceived the subject matter that is disclosed and claimed in Application serial number 10/606,721, filed June 26, 2003, prior to October 31, 2002, while employed by the Assignee, Northrop Grumman Corporation (then TRW Inc.).

3. I submit that I prepared ten invention disclosures during the time period from September through December, 2002. Upon preparing the invention disclosures, I submitted them to one or more other people assigned to the respective project. One such invention

disclosure, attached hereto as Exhibit A, is dated prior to October 31, 2002, and establishes conception and support of at least the systems, methods, and devices recited in claims 1, 3-6, 14-17, 19, and 22-26 of the present application prior to October 31, 2002. Specifically, the fifth paragraph under the heading "Inventive Concept" beginning on page 4 of 7 and continuing to page 5 of 7 and the first six paragraphs under the heading "Invention Description and Operation" on page 5 of 7 support these claims.

4. I submit that I updated the invention disclosure of Exhibit A as invention disclosure Docket No 48-0057, attached hereto as Exhibit B. The invention disclosure of Exhibit B references the previous invention disclosure, Exhibit A, as a Date of First Written Description of the Invention having a date prior to October 31, 2002, and thereby supports the conception of at least the systems, methods, and devices recited in claims 1, 3-6, 14-17, 19, and 22-26 prior to October 31, 2002. Specifically, the fifth paragraph under the heading "Inventive Concept" on page 5 of 9, the first six paragraphs under the heading "Invention Description and Operation" beginning on page 5 of 9 and continuing into page 6 of 9, and Figure 1 on page 7 of 9 support these claims.

5. On December 9, 2002, Lorna Schott, Patent Administrator for Northrop Grumman Space & Mission Systems Corp. Space Technology, prepared a first letter to Christopher Harris, attached hereto as Exhibit C, that included invention disclosures that I prepared for Northrop Grumman Docket Nos. 20-0191, 48-0042, 48-0040, 48-0041, and 48-0045. The letter requests that patent applications be prepared for these invention disclosures. On December 24, 2002, Lorna Schott prepared a second letter to Christopher Harris, attached hereto as Exhibit D, that included invention disclosures that I prepared for Northrop Grumman Docket Nos. 48-0043, 48-0046, and 48-0049. The letter requests that patent applications be prepared for these invention disclosures.

6. We submit that the invention disclosure of Exhibit B was uploaded onto the TRW Inc. website on December 26, 2002, upon its review by my co-inventor, Frank Winter. This is demonstrated in an email from Lorna Schott to Christopher Harris, attached hereto as Exhibit E.

The email of Exhibit E also describes that Barry Dunbridge, the Invention Evaluation Chairman, sent the invention disclosure of Exhibit B to technical reviewers for technical evaluation on January 8, 2003. We submit that the last review was received by Barry Dunbridge on January 17, 2003, and that a meeting was held and a decision to pursue patent protection for the invention described in the invention disclosure of Exhibit B was made on January 20, 2003, as also demonstrated in the email of Exhibit E.

7. On or about January 18-19, 2003, I and my co-inventor Frank Winter had meetings with Christopher Harris and Gary Pitzer on the eight Northrop Grumman Patent disclosures referenced in Exhibits D and E of which Mr. Harris and Mr. Pitzer were assigned to prepare and file patent applications on the respective subject matter of each disclosure. The disclosures included the Northrop Grumman Docket Nos. 20-0191, 48-0040, 48-0041, 48-0045, 48-0049, 48-0043, 48-0046, and 48-0042 referenced in Exhibits D and E.

8. On or about January 27, 2003, Frank Winter and I had a teleconference with Christopher Harris regarding two new invention disclosures: Northrop Grumman Docket No. 48-0057, which discloses the subject matter of the present application, and Northrop Grumman Docket No. 48-0058. This teleconference and receipt of these invention disclosures is described in an email from Lorna L. Schott on January 27, 2003, to Christopher Harris. The email of Exhibit C describes that Lorna Schott prepared the email to Christopher Harris on January 21, 2003, which was forwarded to Christopher Harris on January 27, 2003. The email is attached hereto as Exhibit F.

9. During the course of the next 4-6 months, I reviewed and commented on some or all of the ten draft patent applications written from the above-mentioned ten patent disclosures. Attached Exhibit G demonstrates a series of emails from Christopher Harris and Gary Pitzer to either Marilyn Beaumont, patent administrator for Northrop Grumman, or to myself with attached patent application drafts for the invention disclosures referenced in Exhibits D and E for my review for technical accuracy and completeness. Specifically, Exhibit G includes an email dated February 13, 2003, regarding Docket No. 20-0191, an email dated February 13, 2003,

regarding Docket No. 48-0040, an email dated February 17, 2003, regarding Docket No. 48-0042, an email dated February 24, 2003, regarding Docket No. 48-0049, an email dated March 24, 2003, regarding Docket No. 48-0046, an email dated March 26, 2003, regarding Docket No. 48-0043, an email dated March 27, 2003, regarding Docket No. 48-0045, an email dated April 14, 2003, regarding Docket No. 48-0041, and an email dated April 24, 2003, regarding Docket No. 48-0058.

10. On May 8, 2003, Christopher Harris contacted me via email to request that I review a draft application for the above-identified patent application Serial No. 10/606,721 for technical accuracy and completeness. The email included an electronic copy of a draft of the Application. The email is attached hereto as Exhibit H. A copy of the draft of the Application is attached hereto as Exhibit I.

11. At some time prior to June 21, 2003, I sent an email to Christopher Harris containing my comments and revisions regarding the draft of the Application.

12. On the morning of June 21, 2003, Christopher Harris provided a revised second draft of the Application via email. A copy of that email is attached hereto as Exhibit J.

13. On June 23, 2003, I received electronic copies of the Application and a set of formal papers via email from Christopher Harris. A copy of that email is attached as Exhibit K. I signed the formal papers confirming that I am a coinventor of the invention described in the Application and assigning my interest in any patent granted from the Application to Northrop Grumman Corporation. I then promptly mailed the signed papers back to Christopher Harris for submission with the Application.

14. I believe that the Application was filed in the U.S. Patent Office on June 26, 2003.

15. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Ian Robinson

July 27, 2007
Date

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)	
	)	
Ian Robinson, et al.	)	Group Art Unit: 2611
	)	
Serial No.: 10/606,721	)	
	)	
Filed: June 26, 2003	)	Examiner: Kevin Michael Burd
	)	

For: *Communication System and Method for Improving Efficiency*

DECLARATION UNDER 37 C.F.R. §1.131

Sir:

I, the undersigned, declare as follows:

1. I, Frank Winter, am an inventor of the invention entitled Communication System and Method for Improving Efficiency, disclosed and claimed in U.S. Patent Application Serial No. 10/606,721 (hereinafter to as "the Application"), which was filed on June 26, 2003.

2. I along with my co-inventor, Ian Robinson, conceived the subject matter that is disclosed and claimed in Application serial number 10/606,721, filed June 26, 2003, prior to October 31, 2002, while employed by the Assignee, Northrop Grumman Corporation (then TRW Inc.).

3. I submit that I reviewed an invention disclosure, attached hereto as Exhibit A, that was prepared by my co-inventor Ian Robinson. The invention disclosure is dated prior to October 31, 2002, and thereby establishes conception and support of at least the systems, methods, and devices recited in claims 1, 3-6, 14-17, 19, and 22-26 prior to October 31, 2002. Specifically, the fifth paragraph under the heading "Inventive Concept" beginning on page 4 of 7

and continuing to page 5 of 7 and the first six paragraphs under the heading "Invention Description and Operation" on page 5 of 7 support these claims.

4. I submit that I reviewed an updated version of the invention disclosure of Exhibit A, attached hereto as Exhibit B. The invention disclosure references the previous invention disclosure, Exhibit A, as a Date of First Written Description of the Invention having a date prior to October 31, 2002, and thereby supports the conception of at least the systems, methods, and devices recited in claims 1, 3-6, 14-17, 19, and 22-26 prior to October 31, 2002. Specifically, the fifth paragraph under the heading "Inventive Concept" on page 5 of 9, the first six paragraphs under the heading "Invention Description and Operation" beginning on page 5 of 9 and continuing into page 6 of 9, and Figure 1 on page 7 of 9 support these claims.

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9. During the course of the next 4-6 months, I reviewed and commented on some or all of the ten draft patent applications written from the above-mentioned ten patent disclosures. Attached Exhibit G demonstrates a series of emails from Christopher Harris and Gary Pitzer to either Marilyn Beaumont, patent administrator for Northrop Grumman, or to myself with attached patent application drafts for the invention disclosures referenced in Exhibits D and E for my review for technical accuracy and completeness. Specifically, Exhibit G includes an email dated February 13, 2003, regarding Docket No. 20-0191, an email dated February 13, 2003, regarding Docket No. 48-0040, an email dated February 17, 2003, regarding Docket No. 48-0042, an email dated February 24, 2003, regarding Docket No. 48-0049, an email dated March 24, 2003, regarding Docket No. 48-0046, an email dated March 26, 2003, regarding Docket No. 48-0043, an email dated March 27, 2003, regarding Docket No. 48-0045, an email dated April 14, 2003, regarding Docket No. 48-0041, and an email dated April 24, 2003, regarding Docket No. 48-0058.

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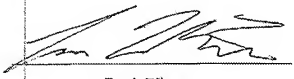
12. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.



Frank Winter

06-26-2008

Date

Invention Disclosure Form – Part 1

EXHIBIT A

Jump to:

Invention Title and Date of this Disclosure Form

Docket: *(Patent office use only)*

Date: October 5, 2002

Title of Invention: : Communications System Enabling High Efficiency and High Linearity

Conception of Invention

Date of First Written Description of the Invention:

Identify the Written Description and Indicate Where Located: Hard drive of inventor

Date of the First Oral Disclosure:	Unknown	To Whom:	
Date of First Sketches or Formal Drawings:		Present Location of Sketches or Drawings:	Hard drive of Inventor

☐ Drawings ☐ x

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Construction And Test Please attach a copy of any dated test reports (or relevant portions).

Invention Simulated / Modeled?	Yes ☐	No ☒	Date:	
			By Whom:	
Invention Physically Constructed?	Yes ☐	No ☒	Date:	
			By Whom:	
Invention Successfully Tested?	Yes ☐	No ☒	Date:	
			By Whom:	

Contract or Project Information

The Invention First Conceived While Charging Time to Job No.: 94KKAC

And Working On:

Government Contract or Subcontract No.: _____ Title: _____

TRW Funded (IR&D, B&P, PM&P) Project No.: 02412007 Title: Universal Base Transceiver Station

Commercial Contract Name or Number: _____ Customer: _____

Other, _____

Contract Administrator and Phone No.: _____

The Invention First Constructed While Charging Time to Job No.: _____

And Working On:

Government Contract or Subcontract No.: _____ Title: _____

TRW Funded (IR&D, B&P, PM&P) Project No.: _____ Title: _____

Commercial Contract No.: _____ Customer: _____

Other, _____

Contract Administrator and Phone No.: _____

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Offer For Sale

Was invention disclosed to a non-TRW employee in the course of negotiation or execution of a sales transaction, or is such a disclosure imminent? Yes ☐ No ☒

Is it anticipated that an activity will occur soon? Please provide the appropriate information below and enter expected date. Yes ☐ No ☒

(If no, continue to Public Use section)

Date of First Executed Sales Contract: _____

Identify First Sales Contract No.: _____

Date Of First Delivery To Customer: _____

Was Invention Described in a Proposal?	Yes ☐	No ☐	Date: _____
Was a Description of the Invention Provided to the Government?	Yes ☐	No ☐	Date: _____
Was a Description of the Invention Provided to a Commercial Customer?	Yes ☐	No ☐	Date: _____
Was a Description of the Invention Provided as Part of an On-going Contract?	Yes ☐	No ☐	Date: _____

If you answered YES to any of the above questions, please provide a copy of the material which included the description.

Public Use

Has the invention been used in a public setting? Yes ☐ No ☒

If the invention is a manufacturing method or machine, has the invention been used to produce products delivered or deliverable to a customer? Yes ☐ No ☒

If the invention is a product, has the product been delivered to someone outside TRW? Yes ☐ No ☒

If you answered YES to any of the above questions, please provide details.

Publication

Has a Description of the Invention Been Published or Described in a Customer Report? Yes ☐ No ☒

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

If Yes, *Provide a Copy* and Identify Publication by Name, Customer, Date, and Number:

Did the Customer Report Have a TRW Proprietary Legend? Yes ☐ No ☐

Has the Invention Been Described to People Not Employed by TRW? Yes ☐ No ☒

If Yes (A) Was Disclosure Under a Confidential Disclosure Agreement?

(B) Provide Names of Person(S), Their Employers(S), Date, and Place of Disclosure:

Prior Art Reference Material

Identify Any Prior TRW Invention Disclosures, Patent Applications, or Issued Patents Relating to the Invention: (Provide TRW Docket No. or Patent No. if Available)

Identify Any other Patents, Printed Publications, Written Reports, or Proposals That You Are Aware Of Relating to Closely Analogous Concepts, and *Provide Copies:*

Technical Evaluation:

Please enter codes corresponding to ALL technology areas that you believe describe your invention.

4, 5, 13

Category	Code	Category	Code
Antennas	1	Military	10
Automotive Electronics	2	Miscellaneous	11
Avionics	3	Photonics	12
Communication Systems	4	Satellite Communications	13
Electronics	5	Semiconductors	14
Energy Systems	6	Sensors	15
Lasers	7	Space	16
Materials	8	Superconductors	17
MEMS	9		

What was the problem or need that you were trying to solve?

High Power, multi-carrier Wideband Code Division Multiple Access (WCDMA) signal amplification at much higher DC to RF efficiency than ever produced, while simultaneously meeting stringent linearity specifications.

Inventive Concept – What is new, what it does and how it does it?

The present invention improves on prior art techniques to reduce peak communication signals to a greater

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Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

degree while limiting degradations to signal error vector magnitude (EVM) and receiver bit error rate (BER) or symbol error rate (SER).

Transmitter cost, electical consumption, and costs related to supply power and cooling can all be driven to large values by signals with high peak-to-average rations (PARs). Signals with lower PAR and accordant peak power level can be amplified more efficiently using smaller, lower cost amplifiers, than an unmodified signal. Alternatively, a transmitter using a linear amplifier (class A, A/B, B) will provide outputs with lower distortions and reduced OOB if the peak signals are reduced. Designers can optimize the level of efficiency achieved, device size, and system linearity.

Existing techniques to reduce PAR must content with the resultant degradations to wanted signals (characterized by EVM) and out-of-band (OOB) emissions. The present invention uses constellation shaping to avoid OOB emissions but it must contend with constraints on EVM. Existing techniques modify the modulation constellation of signal to reduce peaks, deliberately introducing errors in the modulation. A bit or symbol transmitted with an erroneous modulation normally can not be corrected at the receiver and has an increased probability of resulting in a bit or symbol error.

The present invention enables greater PAR reduction by defining one or more additional signals to be used at selected clipping levels to allow the receiver to correctly interpret the bit or symbol modulation without error. Some additional power or bandwidth or both may be needed to provide the additional signal(s) but the DC-RF efficiency and bill of materials cost of the transmitter can be markedly reduced.

Invention Description and Operation: (Attach drawings or sketches, if available)

The present invention operates in several fashions. In all cases a signal processing function is employed to modify the modulation constellation. When a peak would normally occur the constellation is modified into one or more predefined states. Simultaneously or immediately there after a second signal is generated with terms that define the alterations performed to the constellation.

As an example, if a chip value in a coded signal ought to have a value 10 dB PAR then it is modified to be only 2 dB PAR and a second signal is sent so that the receiver can make the necessary adjustment. A simple system uses a minimal second signal that is zero most of the time and takes one or a small number of values coded to a fixed scaling factor when a signal is clipped.

There are preferred methods of supplying the second signal but other methods are possible. For communications using code channels (e.g. CDMA, WCDMA, CDMA2000, spread spectrum) the addition of a unique code channel(s) is easily adopted for the additional signals.

For systems using multiple carriers to convey information (e.g. OFDM, MC-CDMA, DMT) the allocation of one or a few specific frequencies can be used. It may be necessary for the receiver to buffer data for a short period to extract the additional signals.

For systems operating with TDMA it is possible to send an additional time slot with the secondary scaling information. Clearly this sacrifices some capacity for the benefits inherent in the present invention.

It is also possible to add a carrier or a polarization coded to show the additional information for nominally single carrier systems. This technique may require more extensive functions at the receiver.

It is also possible to add a code channel to signals that use other techniques.

With the addition of these techniques the PAR level of complex communications signals can be significantly

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Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

decreased. Reducing a four carrier WCDMA signal from a PAR of 10 dB to a PAR of 5 dB is well within reach. This change enables a 3x reduction in amplifier size and cost and will allow a class A/B amplifier transmitter to double its DC-RF efficiency from less than 10% to almost 20%.

Briefly describe what the prior art taught:

Prior art has taught several techniques to reduce PAR levels including modification of the modulation constellation, clipping, and selection of optimum signal components (e.g. carrier phase, code selection, frequency, code timing offset). These are techniques to limit the creation of peaks. Referencing Figure 3, selection of component control can reduce the probability of a high peak and reduce the maximum peak. In this figure 100 combinations of code offsets are selected for a four-carrier WCDMA case. Shown are the resultant minimum, median, and maximum PAR cases where there is almost a 3 dB difference in the min and max peak levels.

In previous wireless systems development getting increased performance (bandwidth and information content) were the priority. Standards and designs were not optimized for reducing PAR and its effects. Most of the prior art has focused on changes that can be made to existing systems by modifying only the transmitter without requiring replacement of legacy receivers.

The present invention can be used with existing standards, albeit requiring modifications to legacy equipment, but may find its greatest application in future standards.

What are the advantages to your invention (performance, cost, enabling new characteristics, etc)?

The present invention enables many transmitter architectures to operate with higher efficiency and much smaller part size and cost. A conventional four-carrier WCDMA system can save 50-100% on the most costly part of the transmitter, the final amplifier device. It can also improve its operating efficiency from less than 10% to more than 15%, resulting in a massive cost savings in base station capital equipment. The impact to new receiver designs is small.

Are there practical alternatives to the system, structure or method of the invention? That is, how easy would it be to design around the claimed invention?

No apparent alternatives are obvious.

Market Evaluation:

Military or Defense applications:

Does the invention have only military or defense applications?

No

TRW applications:

Is the invention used in a current or planned TRW product?

Not at this time. Most likely this concept would be introduced as a future standard to which systems would be built

If Yes, describe the product and expected time to market.

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Sales and Licensing Potential – please fill out this section to the best of your ability. Your answers will help us understand potential markets or licensing opportunities for your invention.

Please describe potential current or future commercial uses for your invention. List specific products that already make use of this invention, or could benefit from the use of it. Be as specific as possible.

Mobile, fixed, airborne, and space-based transmitters.

Are you aware of existing companies that might be interested in license or sale? What companies could benefit from the use of this patent? What companies compete in this technology?

Yes, NOKIA. Ericcson and Motorola are other potential users.

Is your invention easily detected? If a product were to make use of it, what would the process be to verify it?

Large scale adoption without published standards is unlikely. We will know whether this is a part of future standards.

What countries should patent applications for this invention be filed in? Why?

US, Europe and Japan are major potential markets. Possibly Korea as well. All of these regions have commercial wireless systems in place or planned that could benefit from the present invention.

Feel free to describe any commercial value or opportunities you feel weren't covered by these questions.

The present invention can be used with existing standards, albeit requiring modifications to legacy equipment, but may find its greatest application in future standards. As TRW becomes increasingly involved with setting new IEEE standards and through other groups (ITU, etc), concepts such as the present invention will provide some degree of leverage in the techno-political negotiations.

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Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
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Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Invention Disclosure Form – Part 1

EXHIBIT B

Jump to:

Invention Title and Date of this Disclosure Form

Docket: *48-0057*

Date: November 27 2002

Title of Invention: Communications System Enabling High Efficiency and High Linearity

Conception of Invention

Date of First Written Description of the Invention: October 5, 2002

Identify the Written Description and Indicate Where Located; Hard drive of inventor

Date of the First Oral Disclosure:	Unknown	To Whom:	
Date of First Sketches or Formal Drawings:	November 24, 2002	Present Location of Sketches or Drawings:	Hard drive of Inventor

☐ Drawings ☐ x

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Construction And Test Please attach a copy of any dated test reports (or relevant portions).

Invention Simulated / Modeled?	Yes ☐	No ☒	Date: _____
			By Whom: _____
Invention Physically Constructed?	Yes ☐	No ☒	Date: _____
			By Whom: _____
Invention Successfully Tested?	Yes ☐	No ☒	Date: _____
			By Whom: _____

Contract or Project Information

The Invention First **Conceived** While Charging Time to Job No.: 94KKAC

And Working On:

Government Contract or Subcontract No.: _____ Title: _____

TRW Funded (IR&D, B&P, PM&P) Project No.: 02412007 Title: Universal Base Transceiver Station

Commercial Contract Name or Number: _____ Customer: _____

Other, _____

Contract Administrator and Phone No.: _____

The Invention First **Constructed** While Charging Time to Job No.: _____

And Working On:

Government Contract or Subcontract No.: _____ Title: _____

TRW Funded (IR&D, B&P, PM&P) Project No.: _____ Title: _____

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Other, _____

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Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
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Offer For Sale

Was invention disclosed to a non-TRW employee in the course of negotiation or execution of a sales transaction, or is such a disclosure imminent? Yes ☐ No ☒

Is it anticipated that an activity will occur soon? Please provide the appropriate information below and enter expected date. Yes ☐ No ☒

(If no, continue to Public Use section)

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Date Of First Delivery To Customer: _____

Was Invention Described in a Proposal?	Yes ☐	No ☐	Date: _____
Was a Description of the Invention Provided to the Government?	Yes ☐	No ☐	Date: _____
Was a Description of the Invention Provided to a Commercial Customer?	Yes ☐	No ☐	Date: _____
Was a Description of the Invention Provided as Part of an On-going Contract?	Yes ☐	No ☐	Date: _____

If you answered YES to any of the above questions, please provide a copy of the material which included the description.

Public Use

Has the invention been used in a public setting? Yes ☐ No ☒

If the invention is a manufacturing method or machine, has the invention been used to produce products delivered or deliverable to a customer? Yes ☐ No ☒

If the invention is a product, has the product been delivered to someone outside TRW? Yes ☐ No ☒

If you answered YES to any of the above questions, please provide details.

Publication

Has a Description of the Invention Been Published or Described in a Customer Report? Yes ☐ No ☒

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

If Yes, *Provide a Copy* and Identify Publication by Name, Customer, Date, and Number:

Did the Customer Report Have a TRW Proprietary Legend? Yes ☐ No ☐

Has the Invention Been Described to People Not Employed by TRW? Yes ☐ No ☒

If Yes (A) Was Disclosure Under a Confidential Disclosure Agreement?

(B) Provide Names of Person(S), Their Employers(S), Date, and Place of Disclosure:

Prior Art Reference Material

Identify Any Prior TRW Invention Disclosures, Patent Applications, or Issued Patents Relating to the Invention: (Provide TRW Docket No. or Patent No. if Available)

TRW disclosure being submitted in parallel, *Transmitter with Reduced Dynamic Range and Improved Linearity*

US Patent 5,903,555 Wildhaurer

Identify Any other Patents, Printed Publications, Written Reports, or Proposals That You Are Aware Of Relating to Closely Analogous Concepts, and ***Provide Copies:***

United States Patent 6,307,892
Jones October 23, 2001
Multicarrier Communication System and Method for Peak Power Control

Accompany paper by Kwok on *PAR Reduction Via Constellation Shaping*

Technical Evaluation:

Please enter codes corresponding to ALL technology areas that you believe describe your invention.

4, 5, 13

Category	Code	Category	Code
Antennas	1	Military	10
Automotive Electronics	2	Miscellaneous	11
Avionics	3	Photonics	12
Communication Systems	4	Satellite Communications	13
Electronics	5	Semiconductors	14
Energy Systems	6	Sensors	15
Lasers	7	Space	16
Materials	8	Superconductors	17

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

What was the problem or need that you were trying to solve?

High Power, multi-carrier Wideband Code Division Multiple Access (WCDMA) signal amplification at much higher DC to RF efficiency than ever produced, while simultaneously meeting stringent linearity specifications.

Inventive Concept – What is new, what it does and how it does it?

The present invention is novel in that is has not been described in any publication, known patent, or known patent application. It improves on prior art techniques reducing peak communication signals to a greater degree while limiting degradations to signal error vector magnitude (EVM) and receiver bit error rate (BER) or symbol error rate (SER).

Transmitter cost, electrical consumption, and costs related to supply power and cooling can all be driven to large values by signals with high peak-to-average rations (PARs). Signals with lower PAR and accordant peak power level can be amplified more efficiently using smaller, lower cost amplifiers, than an unmodified signal. Alternatively, a transmitter using a linear amplifier (class A, A/B, B) will provide outputs with lower distortions and reduced OOB if the peak signals are reduced. Designers can optimize the level of efficiency achieved, device size, and system linearity.

Existing techniques to reduce PAR must content with the resultant degradations to wanted signals (characterized by EVM) and out-of-band (OOB) emissions. Disclosure to be submitted *Transmitter with Reduced Dynamic Range and Improved Linearity* teaches a method to clip signals and then reduce the OOB emissions.

The present invention uses constellation shaping to avoid OOB, a technique that modifies the modulation constellation of signal to reduce peaks, deliberately introducing errors in the modulation. A bit or symbol transmitted with an erroneous modulation normally cannot be corrected at the receiver and has an increased probability of resulting in a bit or symbol error.

The present invention enables greater PAR reduction by defining one or more additional signals to be transmitted to instruct the receiver how to revise the modulation. The secondary signals can be sent in parallel or sequentially. They indicate to the receiver the nature of the modification to the modulation constellation so the modification can be partially or wholly reversed. This allows more aggressive peak reduction at the transmitter as EVM errors are repaired at the receiver. Some additional power or bandwidth or both may be needed to provide the additional signal(s) but the DC-RF efficiency and bill of materials cost of the transmitter can be markedly reduced.

This system may be used in conjunction with the methods taught in *Transmitter with Reduced Dynamic Range and Improved Linearity*

Invention Description and Operation: (Attach drawings or sketches, if available)

The present invention operates in several fashions. In all cases a signal processing function is employed to modify the modulation constellation. When a peak would normally occur the constellation is modified into one or more predefined states. Simultaneously or immediately there after a second signal is generated with terms that define the alterations performed to the constellation.

For example if a chip value in a coded signal ought to have a value 10 dB PAR then it is modified to be only

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

2 dB PAR and a second signal is sent so that the receiver can make the necessary adjustment. A simple system uses a minimal second signal that is zero most of the time and takes one or a small number of values coded to a fixed scaling factor when a signal is clipped.

There are preferred methods of supplying the second signal but other methods are possible. For communications using code channels (e.g. CDMA, WCDMA, CDMA2000, spread spectrum) the addition of a unique code channel(s) is easily adopted for the additional signals.

For systems using multiple carriers to convey information (e.g. OFDM, MC-CDMA, DMT) the allocation of one or a few specific frequencies can be used. It may be necessary for the receiver to buffer data for a short period to extract the additional signals.

For systems operating with TDMA it is possible to send an additional time slot with the secondary scaling information. Clearly this sacrifices some capacity for the benefits inherent in the present invention.

It is also possible to add a carrier or a polarization coded to show the additional information for nominally single carrier systems. This technique may require more extensive functions at the receiver.

It is also possible to add a code channel to signals that use other techniques.

With the addition of these techniques the PAR level of complex communications signals can be significantly decreased. Reducing a four carrier WCDMA signal from a PAR of 10 dB to a PAR of 5 dB is well within reach. This change enables a 3x reduction in amplifier size and cost and will allow a class A/B amplifier transmitter to double its DC-RF efficiency from less than 10% to almost 20%.

Figure 1 shows a preferred embodiment in the simplest terms. Many specific examples are possible.

In a second embodiment, the signal is stored briefly (e.g. in digital memory) and is decomposed into two or more replicas whose sum is the wanted signal. These replicas are added to other wanted signals, which may be similarly decomposed. The signals will appear at the receiver to be "multi-path" replicas or signals that have propagated over different paths. Receivers are already designed, for some formats (e.g. rake receivers for CDMA style signals) to recognize and re-combine multi-path versions of a signal.

Briefly describe what the prior art taught:

Prior art has taught several techniques to reduce PAR levels including modification of the modulation constellation, clipping, and selection of optimum signal components (e.g. carrier phase, code selection, frequency, code timing offset). These are techniques to limit the creation of peaks. Referencing Figure 3, selection of component control can reduce the probability of a high peak and reduce the maximum peak. In this figure 100 combinations of code offsets are selected for a four-carrier WCDMA case. Shown are the resultant minimum, median, and maximum PAR cases where there is almost a 3 dB difference in the min and max peak levels.

The TRW patent by Wilderhaur teaches a technique specific to QPSK modulation with BPSK spreading to control peak creation. Appended to this disclosure is a paper by Kwok describing constellation modification techniques. No changes to the receiver are proposed. There is additional prior art trying to optimize communications systems for communications performance but no history of optimizing for production cost and efficiency in any way similar to the present invention.

In previous wireless systems development getting increased performance (bandwidth and information content) were the priority. Standards and designs were not optimized for reducing PAR and its effects.

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Most of the prior art has focused on changes that can be made to existing systems by modifying only the transmitter without requiring replacement of legacy receivers.

The present invention can be used with existing standards, albeit requiring modifications to legacy equipment, but may find its greatest application in future standards. The embodiment using time delayed replicas may require little or no receiver modification for CDMA-style signals.

What are the advantages to your invention (performance, cost, enabling new characteristics, etc)?

The present invention enables many transmitter architectures to operate with higher efficiency and much smaller part size and cost. A conventional four-carrier WCDMA system can save 50-100% on the most costly part of the transmitter, the final amplifier device. It can also improve its operating efficiency from less than 10% to more than 15%, resulting in a massive cost savings in base station capital equipment. The impact to the cost of future receiver designs is small.

Are there practical alternatives to the system, structure or method of the invention? That is, how easy would it be to design around the claimed invention?

No apparent alternatives are obvious.

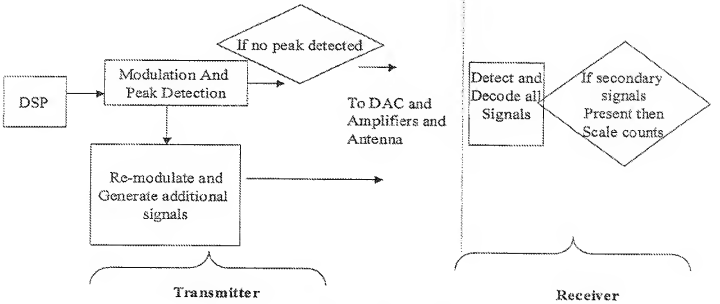
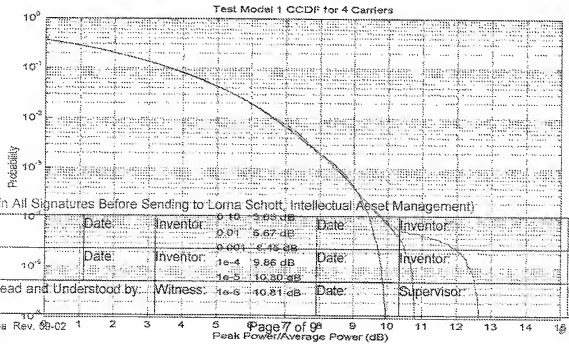


Figure 1. Logical Diagram of Preferred Embodiment



(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:		Date:	

Figure 2. CCDF of WCDMA With Different Code Offsets

Market Evaluation:

Military or Defense applications:

Does the invention have only military or defense applications?

No

TRW applications:

Is the invention used in a current or planned TRW product?

Not at this time. Most likely this concept would be introduced as a future standard to which systems would be built

If Yes, describe the product and expected time to market.

Sales and Licensing Potential – please fill out this section to the best of your ability. Your answers will help us understand potential markets or licensing opportunities for your invention.

Please describe potential current or future commercial uses for your invention. List specific products that already make use of this invention, or could benefit from the use of it. Be as specific as possible.

Mobile, fixed, airborne, and space-based transmitters.

Are you aware of existing companies that might be interested in license or sale? What companies could benefit from the use of this patent? What companies compete in this technology?

Yes, NOKIA. Ericcson and Motorola are other potential users.

Is your invention easily detected? If a product were to make use of it, what would the process be to verify it?

Large scale adoption without published standards is unlikely. We will know whether this is a part of future standards.

What countries should patent applications for this invention be filed in? Why?

US, Europe and Japan are major potential markets. Possibly Korea as well. All of these regions have commercial wireless systems in place or planned that could benefit from the present invention.

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Feel free to describe any commercial value or opportunities you feel weren't covered by these questions.

The present invention can be used with existing standards, albeit requiring modifications to legacy equipment, but may find its greatest application in future standards. As TRW becomes increasingly involved with setting new IEEE standards and through other groups (ITU, etc), concepts such as the present invention will provide some degree of leverage in the techno-political negotiations.

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

TRW

Invention Disclosure Form – Part 2

Docket: *48-0057*

Date: November 27, 2002

Title of Invention: Communications System Enabling High Efficiency and High Linearity

Inventor(s): If there is a non-TRW inventor, please state business relationship and enclose a copy of the current Contract and Non-Disclosure Agreement. (Note: to add more inventors, please press the TAB key after the last entry in the last column to insert a new row.)

Full Name *(No Initials, NMI if no middle name. Please note if you are a consultant.)*	Badge No.	Core Process/ Subsidiary	CCC	TRW Mail Station	Extension	Immediate Supervisor
Ian Robinson	114030	Engineering	D652	03/1633E	22770	Jack Macek
Frank Winter	161528	RS	Q445	RC1 / 3279D	592-3301	Bill Goyette

Home Address *(No P.O. Boxes)*	City	State	Zip Code	Home Phone	Badge #
1079 Marco Place	Venice	CA	90291	310 452-7788	114030
13485 Grandvia Pt	San Diego	CA	92130	858 792 7591	161528

EXHIBIT C

Intellectual Asset Management
E2/6051
310.812.1534
Telecopier 310.812.2687
E-mail: lorna.schott@trw.com

December 9, 2002

VIA E-MAIL

Christopher P. Harris, Esq.
Tarolli, Sundheim, Covell, Tummino & Szabo L.L.P.
526 Superior Avenue
1111 Leader Building
Cleveland, Ohio 44114-1400

Subject: TRW Docket No. 20-0191 (Combined with 48-0042)
Last Day to File Application: **09/23/03**
Gov't. Contract No.: **N/A**
Billing Unit: TRW SE-Engineering - Billing Code: 312

Subject: TRW Docket No. 48-0040
Last Day to File Application: **N/A**
Gov't. Contract No.: **N/A**
Billing Unit: TRW SE-Engineering - Billing Code: 312

Subject: TRW Docket No. 48-0041
Last Day to File Application: **N/A**
Gov't. Contract No.: **N/A**
Billing Unit: TRW SE-Engineering - Billing Code: 312

Subject: TRW Docket No. 48-0045
Last Day to File Application: **N/A**
Gov't. Contract No.: **N/A**
Billing Unit: TRW SE-Engineering - Billing Code: 312

Dear Chris:

Transmitted herewith are copies of the above-referenced invention disclosures. No formal patentability searches will be conducted in these matters. Please provide me with draft application cost estimates.

The first draft applications should be submitted to this office by January 20, 2003. The patent applications should be prepared in accordance with the current U.S. Patent Office Rules. The draft applications and

informal drawings (sketches), along with copies on disk, should be sent to me regular U.S. mail or Airborne. If you prefer to submit these by e-mail, please obtain approval from this office before submitting them PgP encryption.

There are several other inventions that may be related to the above-inventions, so I would suggest that you set up a time to come out to interview the inventors for the above-cases as well as the others to follow. I should have answers on the other inventions in the next couple of weeks and then you can set it all up at once. Please contact Marilyn Beaumont at (310) 812-1518 of this office to set up interview with the inventors. Be sure to provide copies of all transmittals of drafts, documentation and comments to this office, so that I can keep track of the progress of the preparation.

Attached is a list of standards that we require for all patent application preparation. Please follow these guidelines.

The transmittal should confirm whether or not there are any potential statutory bar dates, and whether or not there are any impediments to our filing corresponding foreign applications. **Your firm is also responsible for informing us if there are any related and/or co-pending applications that are to be filed at the same time.**

So that there is no question as to division of responsibilities, this office will be responsible for the preparation of the formal papers (declaration, power of attorney, assignment) and the actual filing of the applications.

I look forward to working with you to obtain the best patent coverage we can for these inventions. If you have any questions concerning these matters, please do not hesitate to contact me.

Sincerely,

Lorna L. Schott
Patent Administrator

Enclosures

EXHIBIT D

NORTHROP GRUMMAN
Space Technology
Intellectual Asset Management
One Space Park
E2/6051
310.812.1534
Telecopier 310.812.2687
E-mail: lorna.schott@trw.com

December 24, 2002

VIA TELECOPIER

Christopher P. Harris, Esq.
Tarolli, Sundheim, Covell, Tummino & Szabo L.L.P.
526 Superior Avenue
1111 Leader Building
Cleveland, Ohio 44114-1400

Subject: Docket No. 48-0043
Last Day to File Application: **N/A**
Gov't. Contract No.: **N/A**
Billing Unit: Space Technology-Engineering - Billing Code: 312

Subject: Docket No. 48-0046
Last Day to File Application: **N/A**
Gov't. Contract No.: **N/A**
Billing Unit: Space Technology-Engineering - Billing Code: 312

Subject: Docket No. 48-0049
Last Day to File Application: **N/A**
Gov't. Contract No.: **N/A**
Billing Unit: Space Technology-Engineering - Billing Code: 312

Dear Chris:

Transmitted herewith are copies of the above-referenced invention disclosures. No formal patentability searches will be conducted in these matters. Please provide me with draft application cost estimates. I am also trying to obtain the inventors schedules so you can come out either January 16-17 or January 20-21. The remaining invention disclosure has been placed on hold. You should still proceed and I will let you know if we plan on filing this one in the next couple of weeks.

The first draft applications should be submitted to this office by February 18, 2003. The patent applications should be prepared in accordance with the current U.S. Patent Office Rules. The draft applications and informal drawings (sketches), along with copies on disk, should be sent to me regular U.S. mail or Airborne. If you prefer to submit these by e-mail, please obtain approval from this office before submitting them PgP encryption.

Be sure to provide copies of all transmittals of drafts, documentation and comments to this office, so that I can keep track of the progress of the preparation.

Attached is a list of standards that we require for all patent application preparation. Please follow these guidelines.

The transmittal should confirm whether or not there are any potential statutory bar dates, and whether or not there are any impediments to our filing corresponding foreign applications. **Your firm is also responsible for informing us if there are any related and/or co-pending applications that are to be filed at the same time.**

So that there is no question as to division of responsibilities, this office will be responsible for the preparation of the formal papers (declaration, power of attorney, assignment) and the actual filing of the applications.

I look forward to working with you to obtain the best patent coverage we can for these inventions. If you have any questions concerning these matters, please do not hesitate to contact me.

Sincerely,

Lorna L. Schott
Patent Administrator

Enclosures

EXHIBIT E

From: "Schott, Lorna (LAW) (Space Technology)" <lorna.schott@ngc.com>
To: "Christopher Harris" <charris@tarolli.com>
Date: 6/20/2008 5:06:06 PM
Subject: RE: Docket Number: 48-0057

Hi Chris,

1. The inventor uploaded the Invention Disclosure into our IAM Website on 12/26/02. This was during TRW Inc.'s Christmas Shutdown (from 12/25/02 through 1/1/03).

2. Barry Dunbridge, Invention Evaluation Chairman, sent the disclosure out to the technical reviewers on 1/8/03 to evaluate the invention.

3. The last review came back to Barry on 1/17/03.

4. Invention Evaluation Meeting was held on 1/20/03 and the decision was made to file for patent protection.

5. I prepared the letter to Tarolli on 1/21/03, but did not get the email enclosing the invention disclosure to Tarolli until 1/27/03.

Hope this helps.

Lorna L. Schott
Patent Administrator

NORTHROP GRUMMAN
Space Technology
Law Dept.
One Space Park, Bldg. E1/2041C
Redondo Beach, CA 90278

Tel.: (310) 812-1534
Fax: (310) 812-2687

-----Original Message-----
From: Christopher Harris [mailto:charris@tarolli.com]
Sent: Friday, June 20, 2008 12:51 PM
To: Schott, Lorna (LAW) (Space Technology)
Subject: Docket Number: 48-0057

Hi Lorna,

The first disclosure of the above-identified matter was dated October 5, 2002 with the second November 27th, 2002. I think the second date was the date sent to legal.

Please check when Northrop actually received this from Ian. I am not sure of your procedure of submitting disclosures.

We received the disclosure on January 27th, 2003 when I was interviewing them in person with Gary.

See if we can establish some sort of agenda that occured between these dates.

Thanks,
Chris Harris

Christopher P. Harris
Tarolli, Sundheim, Covell & Tummino, L.L.P.
1300 East Ninth Street,
Suite 1700
Cleveland, OH 44114
Phone: (216) 621-2234 x104
Fax: (216) 621-4072
Email: charris@tarolli.com
Website: www.tarolli.com

EXHIBIT F

NORTHROP GRUMMAN
Space Technology
Intellectual Asset Management
One Space Park
E2/6051
310.812.1534
Telecopier 310.812.2687
E-mail: lorna.schott@trw.com

January 27, 2003

VIA E-MAIL

Christopher P. Harris, Esq.
Tarolli, Sundheim, Covell, Tummino & Szabo L.L.P.
526 Superior Avenue
1111 Leader Building
Cleveland, Ohio 44114-1400

Subject: Docket No. 48-0057
Last Day to File Application: **N/A**
Gov't. Contract No.: **N/A**
Billing Unit: Space Technology-Engineering - Billing Code: 312

Subject: Docket No. 48-0058
Last Day to File Application: **N/A**
Gov't. Contract No.: **N/A**
Billing Unit: Space Technology-Engineering - Billing Code: 312

Dear Chris:

You should be in receipt of the above-referenced invention disclosures which were delivered to you by Ian Robinson at your invention interview this morning. No formal patentability searches will be conducted in these matters. Please provide me with draft application cost estimates.

The first draft applications should be submitted to this office by March 4, 2003. The patent applications should be prepared in accordance with the current U.S. Patent Office Rules. The draft applications and informal drawings (sketches), along with copies on disk, should be sent to me regular U.S. mail or Airborne. If you prefer to submit these by e-mail, please obtain approval from this office before submitting them PgP encryption.

Be sure to provide copies of all transmittals of drafts, documentation and comments to this office, so that I can keep track of the progress of the preparation.

Attached is a list of standards that we require for all patent application preparation. Please follow these guidelines.

The transmittal should confirm whether or not there are any potential statutory bar dates, and whether or not there are any impediments to our filing corresponding foreign applications. **Your firm is also responsible for informing us if there are any related and/or co-pending applications that are to be filed at the same time.**

So that there is no question as to division of responsibilities, this office will be responsible for the preparation of the formal papers (declaration, power of attorney, assignment) and the actual filing of the applications.

I look forward to working with you to obtain the best patent coverage we can for these inventions. If you have any questions concerning these matters, please do not hesitate to contact me.

Sincerely,

Lorna L. Schott
Patent Administrator

EXHIBIT G

From: Christopher Harris
To: marilyn.beaumont@trw.com
Date: 2/13/03 11:04AM
Subject: CORRECTION Docket No. 20-0191 (Our Ref: NG(ST)-6399) not 38-0021

Hi Marilyn,

Attached is a first draft patent application and related drawings for the above-identified patent disclosure.

The inventors are Frank Winter, Ian Robinson and Walter DeMore.

I look forward to receiving the inventor's comments for revising and/or finalizing the application.

If you have any questions, please do not hesitate to contact me.

PLEASE DISREGARD THE PREVIOUS E-MAIL THAT REFERS TO 38-0021.

Best Regards,
Chris Harris

Christopher P. Harris
Tarolli, Sundheim, Covell & Tummino, L.L.P.
1111 Leader Building
526 Superior Avenue
Cleveland, OH 44114
Phone: (216) 621-2234 x104
Fax: (216) 621-4072
Email: charris@tarolli.com

CC: Christopher Harris

From: Christopher Harris
To: marilyn.beaumont@trw.com
Date: 2/13/03 5:56PM
Subject: Docket No. 48-0040 (Our Ref: NG(ST)-6401)

Hi Marilyn.

Attached is a first draft patent application and related drawings for the above-identified patent disclosure.

The lead inventor is Ian Robinson.

We look forward to receiving the inventor's comments for revising and/or finalizing the application.

If you have any questions, please do not hesitate to contact me.

Best Regards,
Chris Harris

Christopher P. Harris
Tarolli, Sundheim, Covell & Tummino, L.L.P.
1111 Leader Building
526 Superior Avenue
Cleveland, OH 44114
Phone: (216) 621-2234 x104
Fax: (216) 621-4072
Email: charris@tarolli.com

CC: Christopher Harris

From: Christopher Harris
To: marilyn.beaumont@trw.com
Date: 2/17/03 5:50PM
Subject: Docket No. 48-0042 (Our Ref: NG(ST)-6447)

Hi Marilyn,

Attached is a first draft patent application and related drawings for the above-identified patent disclosure.

The lead inventor is Ian Robinson.

We look forward to receiving the inventor's comments for revising and/or finalizing the application.

If you have any questions, please do not hesitate to contact me.

Best Regards,
Chris Harris

Christopher P. Harris
Tarolli, Sundheim, Covell & Tummino, L.L.P.
1111 Leader Building
526 Superior Avenue
Cleveland, OH 44114
Phone: (216) 621-2234 x104
Fax: (216) 621-4072
Email: charris@tarolli.com

CC: Christopher Harris

From: Christopher Harris
To: marilyn.beaumont@trw.com
Date: 2/24/03 11:39AM
Subject: Docket No. 48-0049 (Our Ref: NG(ST)-6422)

Hi Marilyn,

Attached is a first draft patent application and related drawings for the above-identified patent disclosure.

The lead inventor is Ian Robinson.

We look forward to receiving the inventor's comments for revising and/or finalizing the application.

If you have any questions, please do not hesitate to contact me.

Best Regards,
Chris Harris

Christopher P. Harris
Tarolli, Sundheim, Covell & Tummino, L.L.P.
1111 Leader Building
526 Superior Avenue
Cleveland, OH 44114
Phone: (216) 621-2234 x104
Fax: (216) 621-4072
Email: charris@tarolli.com

CC: Christopher Harris

From: Christopher Harris
To: ian.robinson@trw.com
Date: 3/24/03 4:05PM
Subject: Docket No. 48-0046 (Our Ref. NG(ST)-6421)

Hi Ian,

Attached is a first draft patent application in connection with the above-identified disclosure. The application is password protected and I will provide you the password by telephone.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

This e-mail is also to confirm that you are not aware of any statutory bars (e.g., public disclosure of the invention through printed publication - foreign or domestic, public use of the invention, sale of the invention, or foreign or domestic patent applications relating to the invention) that may have an impact on the patentability of the invention.

I look forward to receiving your comments for revising and/or finalizing the application. If you have any questions, please do not hesitate to contact me.

Best Regards,
Chris Harris

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CC: Christopher Harris; Lorna Schott@trw.com

From: Christopher Harris
To: ian.robinson@trw.com
Date: 3/26/03 9:09AM
Subject: Docket No. 48-0043 (Our Ref: NG(ST)-6420)

Hi Ian,

Attached is a first draft patent application and related drawings in connection with the above-identified disclosure.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

This e-mail is also to confirm that you are not aware of any statutory bars (e.g., public disclosure of the invention through printed publication - foreign or domestic, public use of the invention, sale of the invention, or foreign or domestic patent applications relating to the invention) that may have an impact on the patentability of the invention.

I look forward to receiving your comments for revising and/or finalizing the application. If you have any questions, please do not hesitate to contact me.

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CC: Christopher Harris; Lorna.Schott@trw.com

From: Christopher Harris
To: ian.robinson@trw.com
Date: 3/27/03 4:08PM
Subject: Docket No. 48-0045 (Our Ref: NG(ST)-6402)

Hi Ian,

Attached is a first draft patent application and related drawings in connection with the above-identified disclosure.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

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From: Christopher Harris
To: ian.robinson@trw.com
Date: 4/14/03 5:18PM
Subject: Docket No. 48-0041 (Our Ref: NG(ST)-6400)

Hi Ian,

Attached is a first draft patent application and related drawings in connection with the above-identified disclosure.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

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From: Christopher Harris
To: ian.robinson@trw.com
Date: 4/24/03 12:02PM
Subject: Docket No. 48-0058 (Our Ref: NG(ST)-6446)

Hi Ian,

Attached is a first draft patent application and related drawings in connection with the above-identified disclosure.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

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EXHIBIT H

From: Christopher Harris
To: ian.robinson@trw.com
Date: 5/8/03 3:01PM
Subject: Docket No. 48-0057 (Our Ref: NG(ST)-6445)

Hi Ian,

Attached is a first draft patent application and related drawings in connection with the above-identified disclosure.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

This e-mail is also to confirm that you are not aware of any statutory bars (e.g., public disclosure of the invention through printed publication - foreign or domestic, public use of the invention, sale of the invention, or foreign or domestic patent applications relating to the invention) that may have an impact on the patentability of the invention.

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COMMUNICATION SYSTEM AND METHOD FOR IMPROVING EFFICIENCY AND LINEARITY

TECHNICAL FIELD

[0001] The present invention relates generally to electronic devices, and more particularly to a system and method for improving efficiency and linearity in communications.

BACKGROUND OF THE INVENTION

[0002] RF power amplifiers used for wireless communication transmitters, with spectrally efficient modulation formats, require high linearity to preserve modulation accuracy and to limit spectral regrowth. Typically, a linear amplifier, Class-A type, Class-AB type or Class-B is employed to faithfully reproduce inputs signals and to limit the amplifier output within a strict emissions mask. Linear amplifiers are capable of electrical (DC power in to RF power out or DC-RF) efficiencies greater than 50% when operated at saturation. However, they are generally not operated at high efficiency due to the need to provide high linearity. For constant envelope waveforms, linear amplifiers are often operated below saturation to provide for operation in their linear regime. Time varying envelopes present an additional challenge. The general solution is to amplify the peaks of the waveform near saturation, resulting in the average power of the waveform being amplified at a level well backed-off from saturation. The back-off level, also referred to as output power back-off (OPBO), determines the electrical efficiency of a linear amplifier.

[0003] Modern transmitters for applications such as cellular, personal, and satellite communications employ digital modulation techniques such as quadrature phase-shift keying (QPSK) in combination with code division multiple access (CDMA) communication. Shaping of the data pulses mitigates out-of-band emissions from occurring into adjacent channels but produces time-varying envelopes. In addition to amplifying individual waveforms with time varying envelopes, many transmitters (especially in base stations) are being configured to amplify multiple carriers. Multi-carrier signals have high a wide distribution of power levels resulting in a large peak-to-

average ratio (PAR). Therefore, the operation of the linear amplifiers in these types of signals is very inefficient, since the amplifiers must have their supply voltage sized to handle the large peak voltages even though the signals are much smaller a substantial portion of the time. Additionally, the size and cost of the power amplifier is generally proportional to the required peak output power of the amplifier.

[0004] Wideband Code Division Multiple Access (WCDMA), Orthogonal Frequency Division Multiplexing (OFDM), and multi-carrier versions of Global Standard for Mobile Communication (GSM) and Code Division Multiple Access 2000 (CDMA 2000) are wireless standards and application growing in use. Each requires amplification of a waveform with high PAR levels, above 10 dB in some cases. The sparse amount of spectrum allocated to terrestrial wireless communication requires that transmissions minimize out-of-band (OOB) emissions to minimize the interference environment. A linear amplifier used to amplify a waveform with a PAR of 10 dB or more provides only 5-10% DC-RF efficiency. The peak output power for the amplifier is sized by the peak waveform. The cost of the amplifier scales with its peak power.

[0005] Several other circuit costs including heat sinks and DC-DC power supplies scale inversely to peak power and dissipated heat (which results from the electrical inefficiency). Related base station costs of AC-DC power supplies, back-up batteries, cooling, and circuit breakers also scale inversely with efficiency as does the electrical operating costs. Clearly, improving DC-RF efficiency is a major cost saver both for manufacture and operation. Non-linear classes (*e.g.,* Class C, D, E and F type amplifiers) of RF power amplifiers switch the RF devices on and off in or near saturation, and are more efficient than linear classes of operation such as Class-A, Class-AB or Class-B type which conduct during at least half of the RF cycle and are significantly backed off from compression. However, non-linear amplifiers can only be employed with constant envelope signals, such as frequency modulations (FM) and certain forms of phase modulation (PM) signals with modulated amplitudes cause severely distorted outputs from these classes of amplifiers.

[0006] Many modern digital communications systems transmit complex waveforms consisting of multiple carriers, multiple code channels, or other signals that give rise to large, infrequent peaks in signal power. These signals while rich in

information content are costly to transmit in terms of hardware and electrical consumption. Any scheme that reduces the size of the peaks without introducing substantial levels of error is desirable.

SUMMARY OF THE INVENTION

[0007] The following presents a simplified summary of the invention in order to provide a basic understanding of some aspects of the invention. This summary is not an extensive overview of the invention. It is intended neither to identify key or critical elements of the invention nor delineate the scope of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is presented later.

[0008] The present invention relates to a communication system having a communication device that includes a transmitter operative to modify a signal for transmission to reduce peaks associated with the signal. The signal can be modified employing signal shaping, signal clipping, signal decomposition or other techniques to remove peaks associated with the signal. The communication system can also include a communication device that includes a receiver that demodifies the modified signal to reconstruct the originally wanted signal.

[0009] In one aspect of the present invention, one or more instruction signals are transmitted to instruct the receiver how to revise the signal modification enabling substantial peak to average (PAR) reduction. The instruction signal or codes can be sent in a parallel or sequential relationship with the peak reduced input signal. The instruction signals or codes indicate to the receiver the nature of the signal modification (*e.g.*, the modification to the modulation constellation) so the modification can be partially or wholly reversed. This allows more aggressive peak reduction at the transmitter as errors are repaired at the receiver.

[0010] In another aspect of the present invention, the input signal is decomposed into two or more replica signals of the input signal whose sum is the wanted signal. The replica signals can be added to other wanted signals, which may be similarly decomposed. The signals will appear at the receiver to be "multi-path" replicas or signals that have propagated over different paths. The replica signals can be

transmitted with or without an instruction signal. Receivers designed to recognize and re-combine multi-path versions of a signal can be employed without an instruction signal.

[0011] To the accomplishment of the foregoing and related ends, certain illustrative aspects of the invention are described herein in connection with the following description and the annexed drawings. These aspects are indicative, however, of but a few of the various ways in which the principles of the invention may be employed and the present invention is intended to include all such aspects and their equivalents. Other advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 illustrates a schematic block diagram of communication system in accordance with an aspect of the present invention.

[0013] FIG. 2 illustrates a schematic block diagram of a transmitter employing an instruction signal in accordance with an aspect of the present invention.

[0014] FIG. 3 illustrates a schematic block diagram of a transmitter employing an instruction code in accordance with an aspect of the present invention.

[0015] FIG. 4 illustrates a schematic block diagram of a transmitter that decomposes a signal into a plurality of replica signals in accordance with an aspect of the present invention.

[0016] FIG. 5 illustrates a schematic block diagram of a transmitter that decomposes a signal into a plurality of replica signals in accordance with another aspect of the present invention.

[0017] FIG. 6 illustrates a schematic block diagram of a receiver that reconstructs a modified input signal employing a construction signal or code in accordance with another aspect of the present invention.

[0018] FIG. 7 illustrates a schematic block diagram of a transmitter that reconstructs a plurality of replica signals into a wanted signal in accordance with another aspect of the present invention.

[0019] FIG. 8 illustrates a methodology for transmitting and receiving a signal in accordance with an aspect of the present invention.

[0020] FIG. 9 illustrates a methodology for transmitting and receiving a signal in accordance with another aspect of the present invention.

DETAILED DESCRIPTION OF INVENTION

[0021] The present invention relates to a communication system having a communication device with a transmitter that modifies a signal for transmission to reduce peaks associated with the signal. The communication system also includes a communication device with a receiver that demodifies the modified signal to reconstruct the originally wanted signal. The communication system allows for smaller transmission power amplifiers to be employed at the transmitter(s) of the communication devices, since the peaks associated with the transmission signals have been reduced. Additionally, errors associated with peak reduction are mitigated since the receiver is operative to reconstruct the transmission signal to its originally wanted form.

[0022] The present invention reduces peak communication signals to a greater degree than previous communication systems, while limiting degradations to signal error vector magnitude (EVM), receiver bit error rate (BER) or symbol error rate (SER). Existing techniques to reduce peak-to-average ratios (PAR) are content with the resultant degradations to wanted signals (characterized by EVM) and out-of-band (OOB) emissions.

[0023] FIG. 1 illustrates a communication system 10 in accordance with an aspect of the present invention. The communication system 10 includes a first communication device 11 having a transmitter 12 and a second communication device 13 having a receiver 14. The first communication device 11 can be a base station and the second communication device 13 can be a mobile communication unit (MCU) in a wireless communication system. Alternatively, the second communication device 13 can be a base station and the first communication device 11 can be a mobile communication unit (MCU). It is to be appreciated that the two communication device system shown in FIG. 1 is for illustrative purposes, and that the communication system

10 can include a plurality communication devices each having one or more transmitters and receivers.

[0024] The transmitter 12 includes a signal modifier 16 that receives an input signal, for example, from a digital signal processor (DSP) or the like. The signal modifier 16 modifies the input signal to reduce peaks associated therewith. The signal modifier 16 also can generate an instruction signal or an instruction code that defines the modification that has occurred to the input signal to reduce the peaks associated with the input signal. The signal modifier 16 then provides the peak reduced signal and the instruction signal. The instruction signals can be sent in parallel or sequentially with the peak reduced signal. The instruction signal indicates to the receiver 14 the nature of the modification to the modulation constellation, so the modification can be partially or wholly reversed. This allows more aggressive peak reduction at the transmitter 12 as errors are repaired at the receiver 14.

[0025] For example, the signal modifier 16 can employ constellation shaping to reduce the peaks and out-of-band (OOB) emissions associated with peak reduction. Constellation shaping is a technique that modifies the modulation constellation of signal to reduce peaks, deliberately introducing errors in the modulation. A bit or symbol transmitted with an erroneous modulation normally cannot be corrected at the receiver and has an increased probability of resulting in a bit or symbol error. The present invention enables greater peak-to-average ration (PAR) reduction by defining one or more additional signals (instruction signals or instruction codes) to be transmitted with the peak reduced signal. The instruction signals or codes provide the receiver with the necessary information on how to reverse the modifications. Other techniques can be employed to reduce PAR levels including clipping, and selection of optimum signal components (*e.g.,* carrier phase, code selection, frequency, code timing offset).

[0026] For communications using code channels (*e.g.,* CDMA, WCDMA, CDMA2000), the addition of a unique code channel(s) is easily adopted for the additional signals. An allocation of one or a few specific frequencies can be used for systems using multiple carriers to convey information (*e.g.,* OFDM, Multiple Carrier (MC)-CDMA, Discrete Multi-tone (DMT)). In certain situations, it may be necessary for the receiver to buffer data for a short period to extract the additional signals. The

secondary scaling information can be sent in an additional time slot for systems operating with Time Division Multiple Access (TDMA). It is also possible to add a carrier or a polarization coded to show the additional information for nominally single carrier systems. It is also possible to add a code channel to signals that use other techniques.

[0027] In another aspect of the invention, the signal modifier 16 separates or decomposes the input signal into two or more replicas of the input signal scaled in amplitude. Recombining the two or more replicas results in the original wanted input signal. For example, the signal can be stored by the briefly (*e.g.,* in digital memory) by the signal modifier and decomposed into two or more replicas whose sum is the wanted signal. These replicas are added to other wanted signals, which may be similarly decomposed. The signals will appear at the receiver to be "multi-path" replicas or signals that have propagated over different paths. The two or more replicas can be combined with an instruction signal that can be sent in parallel or sequentially. Alternatively, a receiver can be employed that is already designed, for some formats (*e.g.,* rake receivers for CDMA style signals), to recognize and re-combine multi-path versions of a signal without the use of an instruction signal.

[0028] The signal modifier 16 then provides the modified signal(s) with or without the instruction signal to a digital-to-analog converter (DAC) 18. The DAC 18 converts the signals from the digital domain to the analog domain. The analog signals are then provided to an amplifier system 20 for amplification. The amplifier system 20 includes a power amplifier (not shown). The power amplifier can be a linear amplifier (*e.g.,* Class-A, Class-AB, Class-B) or, for some classes of input signal, it can be a non-linear type amplifier (*e.g.,* Class-C, Class-D, Class-E, Class-F) based on desired performance, acceptable efficiency and acceptable OOB emissions. The modified signal (s) with or without the instruction signal are then transmitted over a wireless link *via* an antenna 22.

[0029] In one aspect of the invention, the DAC 18 is a delta sigma modulated DAC (*e.g.,* 1-bit delta sigma DAC, multi-bit delta sigma DAC). Delta Sigma modulation is a technique used to generate a coarse estimate of a signal using a small number of quantization levels and a very high sampling rate. The small number (two for a one-bit quantizer) of quantization levels introduces "quantization" noise into the system. The

effect of oversampling and the use of an integrator feedback-loop in delta-sigma modulation are effective in shifting noise to out-of-band frequencies. The noise shifting properties and introduction of quantization error enables efficient use of subsequent filtering stages to remove noise and produce a more precise representation of the input at a much higher frequency. The delta sigma DACs can be employed to upconvert the input signal directly to radio transmission frequencies, such that further frequency conversion of the signals *via* conventional analog mixers is not required. The radio transmission frequencies can be in radio frequency (RF) ranges (*e.g.*, megahertz range) or in microwave frequency ranges (*e.g.*, gigahertz range).

[0030] An antenna 24 captures transmission signals from the transmitter 12, and provides the transmission signals to a detector/decoder 26. The detector/decoder 26 detects the received signals and decodes and/or demodulates the received signals, which are then provided to a signal demodifier 28. The signal demodifier 28 receives the modified output signal(s) and any instruction signals or codes that originate from the transmitter 12 associated with the modified output signal(s). The signal demodifier 28 then reconstructs the signal based on the instruction signal or code to its original format prior to modification to provide the originally wanted input signal. Alternatively, the signal demodifier 28 can combine one or more replicas of the input signal into the original wanted input signal based on an instruction signal or code, or employing multipath algorithms to reconstruct the original wanted input signal prior to modification by the signal modifier 16. The signal demodifier 28 then provides the demodified reconstructed input signal to an analog-to-digital converter (ADC) 30. The ADC 30 converts the analog signal into a digital signal for further processing by the receiver 14.

[0031] FIG. 2 illustrates a schematic block diagram of a transmitter 40 in accordance with an aspect of the present invention. The transmitter 40 includes a signal or constellation shaper 42. The signal shaper 42 modifies the modulation constellation or signal to reduce peaks. A variety of different constellation shaping techniques can be employed to reduce peaks associated with the input signal. The signal shaper 42 is coupled to a signal generator 44. The signal shaper 42 provides information to the signal generator 44 corresponding to modifications of the input signal by the signal shaper 42. The signal generator 44 then generates an instruction signal or

code that informs the receiver that the input signal has been modified and information associated with that modification. Alternatively, the information associated with that modification can reside at the receiver such that a number of known modifications are performed at the transmitter and reconstructed at the receiver based on a defined instruction signal or code. For example, a simple system can employ a minimal instruction signal that is zero most of the time and takes one or a small number of values coded to a fixed scaling factor when a signal is clipped.

[0032] A signal combiner 46 receives the modified or shaped input signal and the instruction signal or code defining the extent of the modifications (*e.g.*, scaling). The modified or shaped input signal and the instruction signal are combined for transmission. The combination of the shaped input signal and the instruction signal can be sent in parallel or sequentially. The instruction signal can be transmitter after or before the shaped input signal in a sequential manner. Alternatively, the instruction signal can be combined with the shaped input signal and transmitted in parallel. The instruction signal can be modulated into the shaped signal. For example, the addition of a unique code channel (s) can be employed for the instruction signal for communications using code channels (*e.g.*, CDMA, WCDMA, CDMA2000, spread spectrum). The instruction signal can be provided in one or a few specific frequencies in systems employing multiple carriers to convey information (*e.g.*, OFDM, MC-CDMA, DMT). The instruction signal can be provided in an additional time slot for systems operating with TDMA.

[0033] The signal combiner 46 then provides the shaped signal and instruction signal to a DAC 48 (*e.g.*, 1-bit delta sigma DAC, multi-bit delta sigma DAC). The DAC 48 converts the signals from the digital domain to the analog domain. The analog signals are then provided to an amplifier system 50 for amplification. The amplifier system 50 includes a power amplifier (not shown). The power amplifier can be a linear amplifier (*e.g.*, Class-A, Class-AB, Class-B). For a linear amplifier (class A, A/B, B) there is roughly a dB for dB savings in size and cost of the selected amplifier with the peak-to-average ratio (PAR) reduction of the amplification system 50. Therefore, the present invention allows for employment of a power amplifier that is smaller (less

power) and operates more efficiently than amplification systems without PAR reduction. There is also a significant improvement available in DC-RF efficiency.

[0034] FIG. 3 illustrates a transmitter 60 in accordance with another aspect of the present invention. The transmitter 60 includes a digital signal processor (DSP) 62 that generates an input signal for transmission. The input signal can be a single carrier or multi-carrier device. The input signal is then provided to a modulator 64 that modulates the input signal according to a predefined modulation standard (*e.g.*, CDMA, WCDMA). The modulated signal is then provided to a peak detector/ clipper 66. The peak detector / clipper 66 detects and removes peak signals associated with an input signal. The peak detector/ clipper 66 provides a peak reduced input signal to a remodulator 70.

[0035] The peak detector/ clipper 66 also provides information to a signal code generator 68. The signal code generator 68 generates a code associated with the peak reduction. The signal code generator 68 can be a look up table and/or algorithm that provides information regarding modifications to the input signal. The peak reduced input signal and generated code are provided to the remodulator 70 that can demodulate the peak reduced input signal and remodulate the peak reduced input signal with the instruction code embedded therein. Alternatively, the remodulator 70 can provide an additional modulation that modulates the signal instruction code into the already modulated peak reduced input signal.

[0036] The remodulator 70 then provides the peak reduced input signal with the instruction code embedded therein to a DAC 72 (*e.g.*, 1-bit delta sigma DAC, multi-bit delta sigma DAC). The DAC 72 converts the signals from the digital domain to the analog domain. The analog signals are then provided to an amplifier system 74 for amplification. The amplifier system includes a power amplifier that can be a linear amplifier (*e.g.*, Class-A, Class-AB, Class-B). Employing a linear amplifier (class A, A/B, B) in the transmitter 60 will provide outputs with lower distortions and reduced OOB if the peak signals are reduced.

[0037] The techniques of FIGS. 1-3 can result in the PAR level of complex communications signals being significantly decreased. For example, reducing a four carrier WCDMA signal from a PAR of 10 dB to a PAR of 5 dB is well within reach. This

change enables a three times reduction in power amplifier size and cost and will allow a class A/B amplifier transmitter to double its DC-RF efficiency from less than 10% to almost 20%.

[0038] FIG. 4 illustrates a transmitter 80 that generates replica signals in accordance with another aspect of the present invention. The transmitter 80 includes a modulator 82 that modulates an input signal that can be a single carrier or multi-carrier signal. The modulator 82 modulates the input signal according to a predefined modulation standard (*e.g.*, CDMA, WCDMA, OFDM, TDMA). The modulated signal is then provided signal splitter or signal decomposer 84. The signal splitter 84 decomposes the signal into two or more replicas of the input signal with each replica having peak amplitudes that are less than or below the peak amplitudes of the input signal. The two or more replicas are then provided to a parallel-to-serial combiner 86 that sequentially combines the two or more replicas into a predetermined order for transmission.

[0039] The parallel-to-serial combiner 86 then provides the sequentially ordered two or more replicas to a DAC 88 (*e.g.*, 1-bit delta sigma DAC, multi-bit delta sigma DAC). The DAC 88 converts the signals from the digital domain to the analog domain. The analog signals are then provided to an amplifier system 90 for amplification. The amplifier system 90 includes a power amplifier (not shown) that can be a linear amplifier (*e.g.*, Class-A, Class-AB, Class-B). In this aspect of the invention, a receiver operative to reconstruct signals from multipath signals such as that employed in OFDM or the like, can be utilized without any or without substantial modifications to the receiver.

[0040] FIG. 5 illustrates a transmitter 100 that generates replica signals in accordance with another aspect of the present invention. The transmitter 100 includes a modulator 102 that modulates an input signal that can be a single carrier or multi-carrier signal. The modulator 102 modulates the input signal according to a predefined modulation standard (*e.g.*, CDMA, WCDMA, OFDM, TDMA). The modulated signal is then provided to a peak detector 104. The peak detector 104 detects peak signals associated with an input signal and provides information to a signal code generator 108. The signal code generator 108 generates a code associated with the peak reduction.

The signal code generator 108 can be a look up table and/or algorithm that provides information regarding modifications to the input signal.

[0041] The peak detector 104 provides the modulated signal to a signal splitter or signal decomposer 106. The signal splitter 106 decomposes the signal into two or more replicas of the input signal with each replica having peak amplitudes that are less than or below the peak amplitudes of the input signal. For example, the number of replicas and/or the scaling of the replicas can be determined by the peak detector 104. The peak detector 104 provides this information to the signal code generator 108, which generates a code that provides the necessary information to the receiver for reconstructing and rescaling the two or more replicas into the wanted signal. The two or more replicas and the signal code are then provided to a signal combiner 110 that combines the two or more replicas and the instruction code into a predetermined order for transmission.

[0042] The signal combiner 110 then provides the sequentially ordered two or more replicas to a DAC 112 (*e.g.,* 1-bit delta sigma DAC, multi-bit delta sigma DAC). The DAC 112 converts the signals from the digital domain to the analog domain. The analog signals are then provided to an amplifier system 114 for amplification and transmission as an output signal. The amplifier system 114 includes a power amplifier (not shown) that can be a linear amplifier (*e.g.,* Class-A, Class-AB, Class-B) biased to handle the peak reduced replicas, such that operational efficiency of the power amplifier is improved compared to a transmitter without peak reduction.

[0043] FIG. 6 illustrates a receiver 120 in accordance with an aspect of the present invention. The receiver 120 is operative to receive transmission signal that include peak reduced input signals and instruction signals that are received in parallel or sequentially with the peak reduced input signal. The receiver 120 includes a detector /decoder 122 that detects a transmission signal from a transmitter, decodes the detected transmission signal and provides that detected transmission signal to a demodulator 124. The demodulator 124 removes the modulation from the input signal to provide a demodulated input signal to a signal separator 126. The signal separator 126 separates the instruction signal from the input signal. For example, if the instruction code or signal is embedded into the input signal, the signal separator 126 removes the

instruction code or signal from the transmission signal and provides the instruction code or signal to an instruction code or signal resolver 128. Concurrently, the signal separator 126 removes the peak reduced input signal from the transmission signal and provides the peak reduced input signal to a signal scaler 130.

[0044] If the instruction code is a signal that is sequential with the input signal, then the signal separator 126 provides the instruction code or signal portion directly to the instruction code or signal resolver 128, and the peak reduced input signal directly to the signal scaler 130. The instruction information can reside in the instruction code or signal or reside at the receiver where it can be accessed employing the instruction code or signal. The instruction code or signal resolver 128 resolves information associated with the instruction code or signal and provides the appropriate scaling factor to the signal scaler 130. The signal scaler 130 then scales the peak reduced input signal to restore the peak reduced input signal to its original wanted form.

[0045] FIG. 7 illustrates a receiver 140 in accordance with another aspect of the present invention. The receiver 140 is operative to receive transmission signal that includes two or more replicas of the input signal that may or may not include an instruction signal. The receiver 140 includes a detector/ decoder 142 that detects a transmission signal from a transmitter, decodes the detected transmission signal and provides that detected transmission signal to a demodulator 144. The demodulator 144 removes the modulation from the transmission signal to provide a demodulated transmission signal to a buffer 146. The transmission signal includes two or more replicas associated with the wanted signal. The two or more replicas are loaded into the buffer 146 that provides the replicas in parallel or in a predetermined order to a signal reconstructor 148. If an instruction signal or code is employed to determine the number of replicas and/or the scaling associated with the replicas, the instruction signal or code can also be loaded into the buffer 146 to be provided to the signal reconstructor 148. The signal reconstructor 148 then reconstructs the two or more replicas into the originally wanted input signal.

[0046] In view of the foregoing structural and functional features described above, methodologies in accordance with various aspects of the present invention will be better appreciated with reference to FIGS. 8-9. While, for purposes of simplicity of

explanation, the methodologies of FIGS. 8-9 are shown and described as executing serially, it is to be understood and appreciated that the present invention is not limited by the illustrated order, as some aspects could, in accordance with the present invention, occur in different orders and/or concurrently with other aspects from that shown and described herein. Moreover, not all illustrated features may be required to implement a methodology in accordance with an aspect the present invention.

[0047] FIG. 8 illustrates a methodology for transmitting a signal in a communication system in accordance with an aspect of the present invention. The methodology begins at 200 where an input signal is modified to reduced peaks associated with the input signal. The input signal can be an input signal that conforms to a variety of different wireless formats (*e.g.*, WCDMA, OFDM, multi-carrier versions of GSM, CDMA 2000). The input signal can be modified by employing signal or constellation shaping to reduced peaks associated with the input signal. Other techniques can be employed to reduce peak to average (PAR) levels including clipping, and selection of optimum signal components (*e.g.*, carrier phase, code selection, frequency, code timing offset). The methodology then proceeds to 210.

[0048] At 210, an instruction signal or code is generated. The instruction signal or code is associated with modifications of the input signal. At 220, the instruction signal or code is combined with the modified input signal. The instruction signal or code can be combined sequentially (*e.g.*, transmitted in sequence) or in parallel (*e.g.*, instruction signal or code combined within the modulation of the input signal). For example, the addition of a unique code channel(s) can be employed for the instruction signal for communications using code channels (*e.g.*, CDMA, WCDMA, CDMA2000, spread spectrum). The instruction signal can be provided in one or a few specific frequencies in systems employing multiple carriers to convey information (*e.g.*, OFDM, MC-CDMA, DMT). The instruction signal can be provided in an additional time slot for systems operating with TDMA. At 230, the combined modified input signal and instruction signal or code is converted from the digital domain to the analog domain, amplified and transmitted as a transmission signal over a wireless link. The methodology then proceeds to 240.

[0049] At 240, a receiver receives the transmission signal by detecting and decoding the transmission signal. The transmission signal is then demodulated to remove the modulation associated therewith. At 250, the instruction signal and the modified input signal are separated. The instruction signal and the modified input signal can be separated by removing the instruction signal or code embedded in the modified input signal or by temporarily storing the instruction signal and the modified input signal in a buffer or the like. The instruction signal is then employed to reconstruct the modified input signal into the originally wanted signal at 260. For example, the instruction signal can be employed to select a scaling factor to scale the modified input signal to its original form at peak areas or to a fixed scale over the entire modified input signal. It is to be appreciated that a variety of other techniques can be employed to reconstruct the modified input signal into the originally wanted signal.

[0050] FIG. 9 illustrates a methodology for transmitting a signal in a communication system in accordance with another aspect of the present invention. The methodology begins at 300 where an input signal is decomposed into a plurality of replica signals. The input signal can be an input signal that conforms to a variety of different wireless formats (*e.g.*, WCDMA, OFDM, multi-carrier versions of GSM, CDMA 2000). At 310, the plurality of replica input signals can be temporarily loaded into a buffer for transmission. At 320, the plurality of replica signals are combined sequentially with or without an instruction signal to provide a transmission signal comprised of a plurality of sequential replica signals each having peak signals that are less than the peak signals of the original input signal. The methodology then proceeds to 330.

[0051] At 330, the plurality of sequential replica signals are converted from the digital domain to the analog domain, amplified and transmitted as a transmission signal over a wireless link. The methodology then proceeds to 340. At 340, a receiver receives the transmission signal by detecting and decoding the transmission signal. The transmission signal is then demodulated to remove the modulation associated therewith. At 350, the plurality of replica signals are converted into the digital domain and loaded into a buffer. If the transmission signal includes an instruction signal it is also loaded into the buffer. For example, the number of replicas and/or the scaling of the replicas can be determined by employing an instruction signal. At 360, the plurality

of replica signals are reconstructed into the original wanted input signal with or without employing an instruction signal. It is to be appreciated that many receivers exist that employ algorithms to recombine multipath signals that resemble the replica signals of the present invention.

[0052] What has been described above includes exemplary implementations of the present invention. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the present invention, but one of ordinary skill in the art will recognize that many further combinations and permutations of the present invention are possible. Accordingly, the present invention is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims.

What is claimed is:

1. A communication device comprising:

a signal modifier that modifies an input signal to reduce peak signals associated with the input signal and provides a peak reduced input signal; and

a power amplifier that amplifies the peak reduced input signal and an instruction signal associated with modifications of the input signal by the signal modifier, the instruction signal being employed by a receiver to reconstruct the input signal to its original form prior to modification.

2. The communication device of claim 1, the signal modifier comprising a signal shaper that shapes a modulation constellation of the input signal to reduce peak signals associated with the input signal.

3. The communication device of claim 1, further comprising a signal combiner that combines the instruction signal in one of a parallel and a sequential relationship with the peak reduced input signal.

4. The communication device of claim 1, the instruction signal being an instruction code that is modulated into the peak reduced input signal.

5. The communication device of claim 1, the input signal conforming to one Wideband Code Division Multiple Access (WCDMA), Orthogonal Frequency Division Multiplexing (OFDM), Global Standard for Mobile Communication (GSM), Code Division Multiple Access (CDMA 2000) and Time Division Multiple Access (TDMA).

6. The communication device of claim 1, further comprising a digital-to-analog converter (DAC) that converts the peak reduced input signal and the instruction signal from the digital domain to the analog domain directly to radio transmission frequencies, and provides an analog peak reduced input signal and an analog instruction signal to the power amplifier for amplification.

7. The communication device of claim 1, the signal modifier comprising a signal splitter that decomposes the input signal into a plurality of replica signals, each of the plurality of replica signals having a maximum peak value below the maximum peak value of the input signal.

8. The communication device of claim 7, further comprising a signal combiner that sequential orders the plurality of replica signals for transmission.

9. A communication device comprising:

a detector/ decoder that receives a transmission signal that contains a modified input signal and an instruction signal from a transmitter, the instruction signal being associated with modifications of the input signal; and

a reconstructor that reconstructs the modified input signal to its original form prior to modification employing information associated with the instruction signal.

10. The communication device of claim 9, further comprising a signal separator that separates the modified input signal from the instruction signal and an instruction resolver that resolves the instruction signal to provide information to the reconstructor to facilitate reconstruction of the modified input signal to its original form prior to modification.

11. The communication device of claim 9, further comprising a signal scaler that scales the modified input signal based on information associated with the instruction signal.

12. A communication device comprising:

a signal splitter that decomposes an input signal into a plurality of replica signals, each of the plurality of replica signals having a maximum peak value below the maximum peak value of the input signal;

a signal combiner that sequential orders the plurality of replica signals for transmission; and

a power amplifier that amplifies the sequentially ordered plurality of replica signals to provide a transmission signal.

13. The transmitter of claim 12, the signal combiner combines an instruction signal with the plurality of replica signals, the instruction signal informs a receiver of at least one of the number of replica signals and scaling associated with the replica signals.

14. A communication system comprising:

means for modifying an input signal to provide a modified input signals having reduced peak signals;

means for generating an instruction signal associated with reconstructing the input signal to its original form prior to modification;

means for transmitting a transmission signal that includes the modified input signal and the instruction signal;

means for receiving the transmission signal; and

means for reconstructing the input to its original form prior to modification employing the instruction signal.

15. The system of claim 14, further comprising means for combining the modified input signal and the instruction signal into the transmission signal.

16. The system of claim 14, the means for modifying comprising means for decomposing the input signal into a plurality of replica signals, each having a maximum peak signal below the maximum peak signal of the input signal, and means for sequentially ordering the plurality of replica signals into a transmission signal.

17. A method of transmitting a signal in a communication system comprising:

modifying an input signal to reduce peak signals associated with the input signal;

generating an instruction signal or code associated with information relating to the peak reduction of the input signal;

combining the modified input signal and the instruction signal or code into a transmission signal;

converting the transmission signal from the digital domain to the analog domain;

amplifying the transmission signal; and

transmitting the transmission signal.

18. The method of claim 17, the combining the modified input signal and the instruction signal or code into a transmission signal comprising one of combining the instruction signal or code with the transmission signal in one of a parallel and a sequential relationship.

19. The method of claim 17, further comprising separating the modified input signal from the instruction signal or code and reconstructing the modified input signal to its original form prior to peak reduction based on information associated with the instruction signal or code.

20. A method of transmitting a signal in a communication system comprising:

modifying an input signal into a plurality of replica signals, each of the plurality of replica signal having a peak signal below the maximum peak signal of the input signal;

sequentially ordering the plurality of replica signals into a transmission signal;

converting the transmission signal from the digital domain to the analog domain;

amplifying the transmission signal; and

transmitting the transmission signal.

21. The method of claim 20, further comprising reconstructing the plurality of replica signals into its original form prior to modification.

COMMUNICATION SYSTEM AND METHOD FOR IMPROVING EFFICIENCY AND LINEARITY

ABSTRACT

A communication system and method is provided that modifies a signal for transmission at a transmitter to reduce peaks associated with the signal. The signal can be modified employing signal shaping, signal clipping, signal decomposition or other techniques to remove peaks associated with the signal. The communication system can also demodifies the modified signal at a receiver to reconstruct the originally wanted signal.

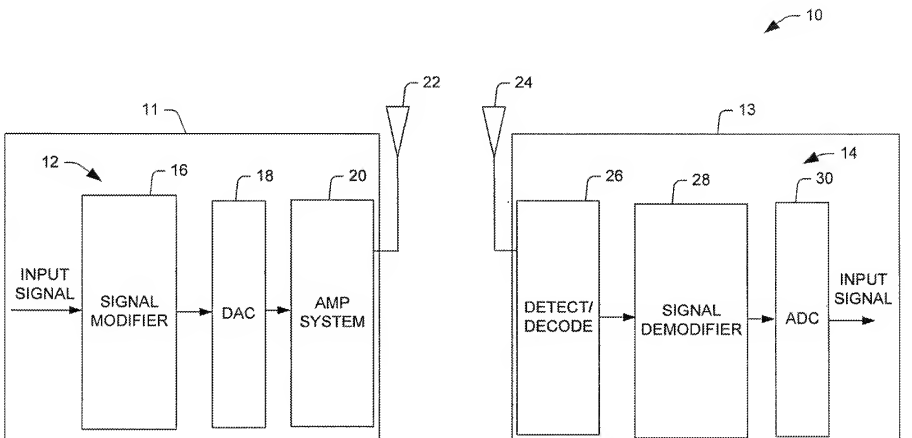
10
11
12
16
18
20
22
24
13
14
26
28
30
INPUT SIGNAL
SIGNAL MODIFIER
DAC
AMP SYSTEM
DETECT/ DECODE
SIGNAL DEMODIFIER
ADC
INPUT SIGNAL

FIG. 1

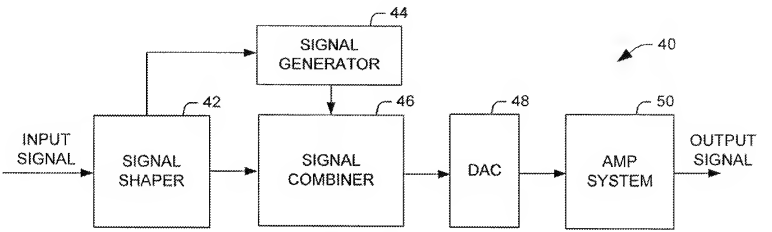
44
SIGNAL GENERATOR
40
42
46
48
50
INPUT SIGNAL
SIGNAL SHAPER
SIGNAL COMBINER
DAC
AMP SYSTEM
OUTPUT SIGNAL

FIG. 2

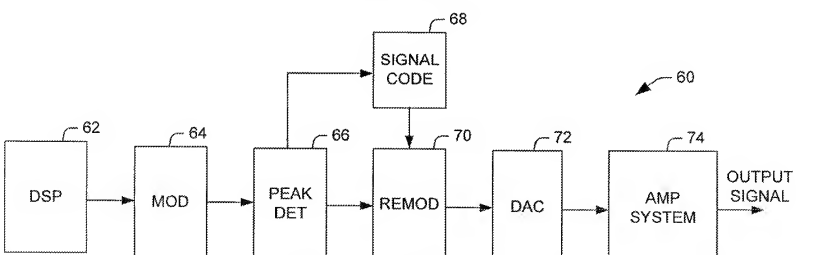
68
SIGNAL CODE
60
62
64
66
70
72
74
DSP
MOD
PEAK DET
REMOD
DAC
AMP SYSTEM
OUTPUT SIGNAL

FIG. 3

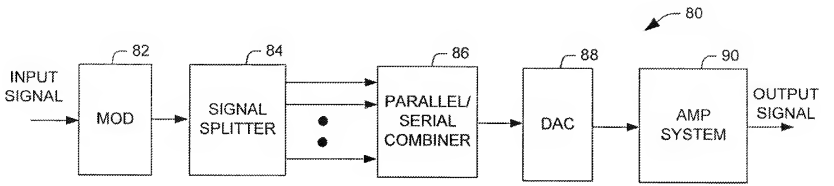
80
82
84
86
88
90
INPUT SIGNAL
MOD
SIGNAL SPLITTER
PARALLEL/ SERIAL COMBINER
DAC
AMP SYSTEM
OUTPUT SIGNAL

FIG. 4

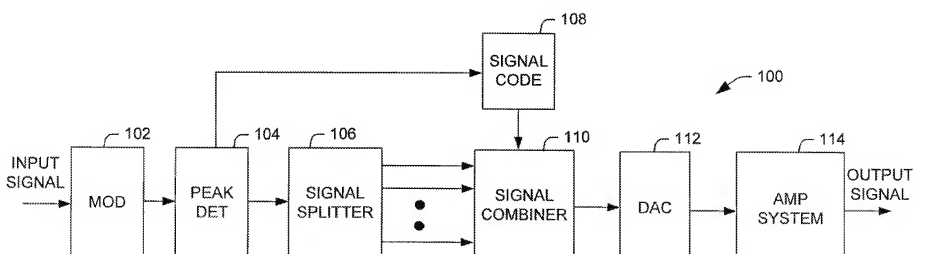
108
SIGNAL CODE
100
102
104
106
110
112
114
INPUT SIGNAL
MOD
PEAK DET
SIGNAL SPLITTER
SIGNAL COMBINER
DAC
AMP SYSTEM
OUTPUT SIGNAL

FIG. 5

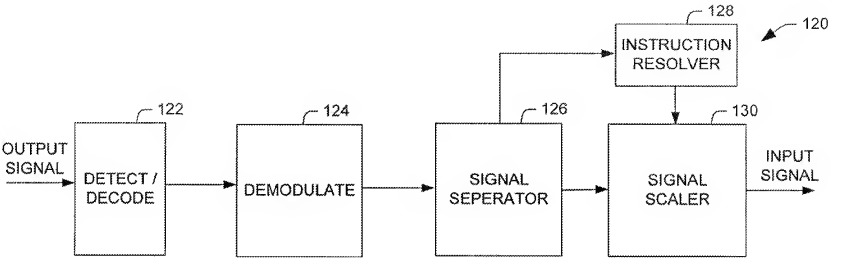
128
120
INSTRUCTION RESOLVER
122
124
126
130
OUTPUT SIGNAL
DETECT / DECODE
DEMODULATE
SIGNAL SEPERATOR
SIGNAL SCALER
INPUT SIGNAL

FIG. 6

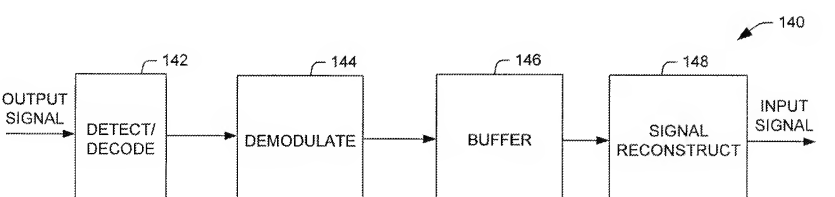
140
142
144
146
148
OUTPUT SIGNAL
DETECT/ DECODE
DEMODULATE
BUFFER
SIGNAL RECONSTRUCT
INPUT SIGNAL

FIG. 7

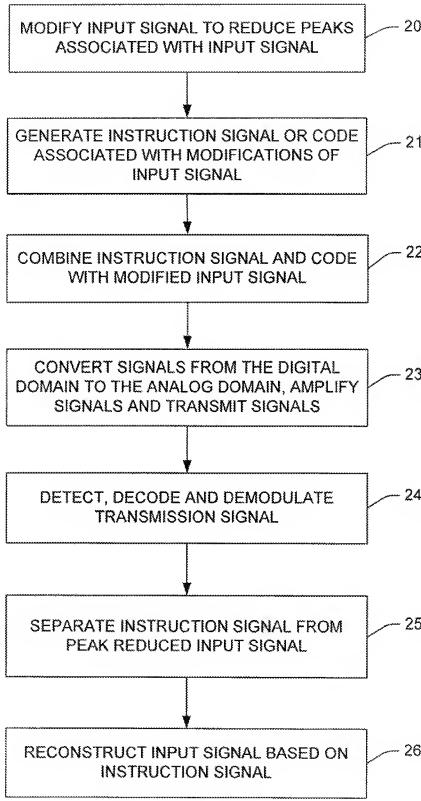
MODIFY INPUT SIGNAL TO REDUCE PEAKS ASSOCIATED WITH INPUT SIGNAL
200
GENERATE INSTRUCTION SIGNAL OR CODE ASSOCIATED WITH MODIFICATIONS OF INPUT SIGNAL
210
COMBINE INSTRUCTION SIGNAL AND CODE WITH MODIFIED INPUT SIGNAL
220
CONVERT SIGNALS FROM THE DIGITAL DOMAIN TO THE ANALOG DOMAIN, AMPLIFY SIGNALS AND TRANSMIT SIGNALS
230
DETECT, DECODE AND DEMODULATE TRANSMISSION SIGNAL
240
SEPARATE INSTRUCTION SIGNAL FROM PEAK REDUCED INPUT SIGNAL
250
RECONSTRUCT INPUT SIGNAL BASED ON INSTRUCTION SIGNAL
260

FIG. 8

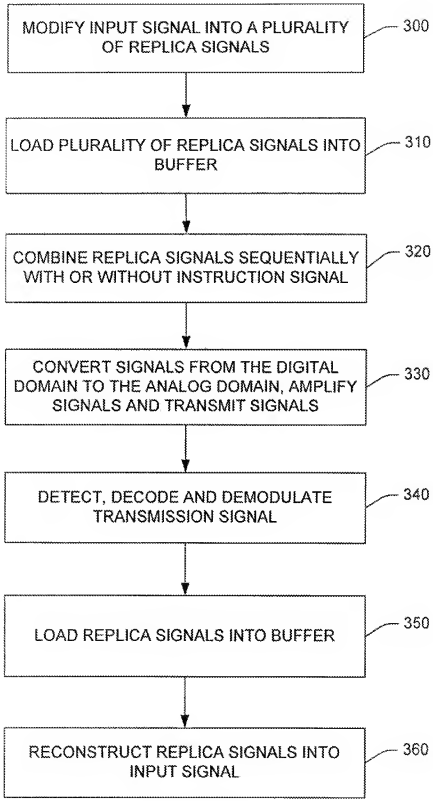
MODIFY INPUT SIGNAL INTO A PLURALITY OF REPLICA SIGNALS
300
LOAD PLURALITY OF REPLICA SIGNALS INTO BUFFER
310
COMBINE REPLICA SIGNALS SEQUENTIALLY WITH OR WITHOUT INSTRUCTION SIGNAL
320
CONVERT SIGNALS FROM THE DIGITAL DOMAIN TO THE ANALOG DOMAIN, AMPLIFY SIGNALS AND TRANSMIT SIGNALS
330
DETECT, DECODE AND DEMODULATE TRANSMISSION SIGNAL
340
LOAD REPLICA SIGNALS INTO BUFFER
350
RECONSTRUCT REPLICA SIGNALS INTO INPUT SIGNAL
360

FIG. 9

EXHIBIT J

From: Christopher Harris
To: ian.robinson@ngc.com
Date: 6/21/03 12:22PM
Subject: Docket No. 48-0057 (Our Ref: NG(ST)-6445)

Hi Ian,

Attached is a second draft patent application redline version and related drawings in connection with the above-identified disclosure.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

I look forward to receiving your comments for revising and/or finalizing the application. If you have any questions, please do not hesitate to contact me.

Best Regards,
Chris Harris

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526 Superior Avenue
Cleveland, OH 44114
Phone: (216) 621-2234 x104
Fax: (216) 621-4072
Email: charris@tarolli.com

CC: Christopher Harris

EXHIBIT K

From: Christopher Harris
To: frank.winter@ngc.com; ian.robinson@ngc.com
Date: 6/23/03 10:30AM
Subject: Docket No. 48-0057 (Our Ref: NG(ST)-6445)

Hi Ian and Frank,

We are also enclosing formal papers (Assignment and Combined Declaration and Power of Attorney) in connection with the above-identified final draft patent application.

Please execute the attached Declaration and Assignment papers by signing and dating them in the spaces provided. Also note that the Assignment must be dated twice with the declaration execution date and the assignment date. Accordingly, please write the date of your signatures in both blanks on the Assignment.

Please return the originally executed formal papers (Assignment and Declaration) to us for prompt filing with the U.S. Patent and Trademark Office.

If you have any questions or comments regarding this matter, please call us immediately.

Best Regards,
Chris Harris

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Email: charris@tarolli.com

CC: Christopher Harris